AD 764340

AMC PAMPHLET

AMCP 706-177

ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

JANUARY 1971

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D. C. 20315

AMC PAMPHLET
No. 706-177*

29 January 1971

ENGINEERING DESIGN HANDBOOK

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 706-177, *Properties of Explosives of Military Interest*, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are listed herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were first compiled for publication at Picatinny Arsenal, Dover, New Jersey, by W. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal, for the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer
Letterkenny Army Depot, ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer proper justification to the address listed in par. a.

c. Government agencies other than DOD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

Commanding General
U. S. Army Materiel Command
ATTN: AMCAM-ABS
Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

Commanding General
U. S. Army Materiel Command
ATTN: AMCRD-TV
Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence
Foreign Liaison Office
Department of the Army
Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a *valid justification*.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

ABBREVIATIONS AND SYMBOLS

~	approximately. This symbol is used before numbers.
AC	Advisory Council on Scientific Research and Development, Great Britain.
ACS	American Chemical Society.
AISI	American Iron and Steel Institute.
Ann	Liebig's Annalen der Chemie.
Ann chim phys	Annales de chimie et de physique.
AP	armor-piercing.
APG	Aberdeen Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-HEC	British Intelligence Overseas Service or Objective Subcommittee, Group 2, Halstead Exploiting Center.
BM	Bureau of Mines, United States Department of Interior.
Bull Soc chim	Bulletin de la societé chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des seances de l'academie des Sciences (Paris).
dec	decomposes.
ΔH	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
E	modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in lb/inch^2.
E'	same as E, but expressed in dynes/cm^2.
Gazz chim ital	Gazzetta Chimica Italiana.
GP	general purpose.
HE	high explosive.
HEAT	high explosive antitank.
Ind Eng Chem	Industrial & Engineering Chemistry.
J Am Chem Soc	Journal of the American Chemical Society
J Chem Ind	The Journal of the Society of Chemical Industry (London).
J Chem Soc	Journal of the Chemical Society (London).
J Frank Inst	Journal of the Franklin Institute.
J Ind Explosives Soc	Journal of the Industrial Explosives Society (Japan).
J prakt Chem	Journal für praktische Chemie.
LA	lead azide
Land-Bornst	Landolt-Bornstein Physikalish-Chemische Tabellen, 5th Edition (Berlin).
M	molar.
M	Monatshefte für Chemie (Wein).
Mém poudr	Mémorial des poudres et salpêtres (Paris).
mg	milligram.

ABBREVIATIONS AND SYMBOLS (cont'd)

min	minimum.
ml	milliliter.
m/s	meters per second.
MW	molecular weight.
NAVORD	Bureau of Ordnance (U. S. Navy)
NC	nitrocellulose.
n_{20}^{D}	index of refraction, with D band of sodium as light source, at twenty degrees centigrade.
NDRC	National Defense Research Committee.
NFOC	National Fireworks Ordnance Corporation.
NG	nitroglycerin.
NOL	U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.
NOTS	U. S. Naval Ordnance Test Station, China Lake, Calif.
NRC	National Research Council.
OB	oxygen balance.
OCM	Ordnance Committee Minutes.
OSRD	Office of Scientific Research and Development
PA	Picatinny Arsenal.
PATR	Picatinny Arsenal Technical Report.
Phil Trans	Philosophical Transactions of the Royal Society of London.
Pogg Ann	Poggendorf's Annalen der Physik.
Proc Roy Soc	Proceedings of the Royal Society of London.
Rec trav chim	Recueil des travaux chimiques des Pays-Bas.
RH	relative humidity.
RI	Report of Investigation.
SAE	Society of Automotive Engineers.
SAP	semi-armor-piercing.
sol	solution.
Spec	Specifications.
std dev	standard deviation.
TM	Technical Manual, Department of the Army.
TM/TO	joint publication, as a TM and as a Department of the Air Force Technical Order.
Trans Farad Soc	Transactions of the Faraday Society
vac stab	vacuum stability.
Z angew Chem	Zeitschrift für angewandte Chemie.
Z anorg Chem	Zeitschrift für anorganische und allgemeine Chemie.
Z ges Schiess-Sprengstoffw	Zeitschrift für das gesamte Schiess und Sprengstoffwessen (Munchen).
Z/sec	atoms of oxygen per second.

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METHODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

(1) Name of the explosive in each instance.

(2) "Composition."

(3) "Impact Sensitivity, 2 Kg Wt."

(a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum height at which at least one of 10 trials results in explosion. For the BM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63 ± 2) steel surfaces; in the latter case, it is placed in the depression of a small steel die-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the BM apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the die-cup cavity), and (3) involves a frictional component against the inclined sides).

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*Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated herein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wet the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

1. The weight of explosive tested is 0.007-gm.

2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter, is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.

(4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and unaffected.

(5) "Rifle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is loaded in the same manner as it is loaded for actual use: that is, cast, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/16-inch wall) closed on each end by a cap. The loaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax plug. The loaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is immersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action.

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75°C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100°C. It is also noted whether exposure at 100°C for 100 hours results in explosion.

(9) "Flammability Index." (h)

The measure of the likelihood that a bare charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscopicity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A 10-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

$$\text{MW of mixture} = \frac{100}{\frac{a}{mw_1} + \frac{b}{mw_2} + \frac{c}{mw_3} + \frac{n}{mw_n}}$$

where a, b, c and n are the weight percents of the components, and mw_1, mw_2, mw_3 and mw_n their corresponding molecular weights.

(13) "Oxygen Balance."

The oxygen balance (OB) is calculated from the empirical formula of a compound in percentage of oxygen required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following order:

$$\text{Metal} + O \longrightarrow \text{Metal Oxide}$$

$$C + H_2O \longrightarrow CO + H_2$$

$$CO_2 + H_2 \longrightarrow CO + H_2O$$

$$2CO + O_2 \longrightarrow 2CO_2$$

Procedure for calculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

the oxygen balance: $1600 \left(2X + \frac{Y}{2} - Z\right)$

$\div$ molecular weight of compound = oxygen balance to CO_2 and H_2O, where X = atoms of carbon, Y = atoms of hydrogen, Z = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The carbon/hydrogen (C/H) ratio is calculated as follows:

$$\frac{\text{Number of C atoms } (\%C + \%H)}{\text{Number of H atoms } (100)} = C/H \text{ ratio}$$

(14) "Density."

(15) "Melting Point."

(16) "Freezing Point."

(17) "Boiling Point."

(18) "Refractive Index."

(19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried is heated for 40 hours, in vacuo at the desired temperature.

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 cap, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample crushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquids. (b)

The sand test for liquids is made in accordance with the procedure given for solids except that the following procedure for loading the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead azide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to avoid squeezing the charge. Transfer a weighed portion of 0.400 gm of the test explosive to an aluminum cap, taking precautions when the explosive is liquid to insert the sample in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid explosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap: height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead azide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in grams, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (c)

The amount of sample under test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

$$\text{TNT value} = \frac{10}{\text{sample weight}} \times 100.$$

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-nosed mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TNT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

(b) Method B - A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates as backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

$$\text{Plate dent test value, or relative brisance} = \frac{\text{Sample Dent Depth}}{\text{Dent Depth for TNT at 1.61 gm/cc}} \times 100.$$

(25) "Detonation Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

(3) "Specific Heat."

(4) "Burning Rate."

(5) "Thermal Conductivity."

(6) "Coefficient of Expansion."

(7) "Hardness, Mohs' Scale."

(8) "Young's Modulus."

(9) "Compressive Strength."

(10) "Vapor Pressure."

(11) "Decomposition Equation."

(12) "Armor Plate Impact Test." (j)

(a) 60-mm Mortar Projectile.

A modified 60-mm, M49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (bazooka), 5 gm of 4F black powder, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

(b) 500-lb General Purpose Bombs.

(13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing either inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

(1) "Fragmentation Test." (l)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M20 Booster pellets, and those used with 3-inch HE, M42A1, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 ± 0.10 gm, and 0.480 to 0.485 inch.

The projectile assembled with fuze, actuated by a Blasting Cap, Special, Type II (Spec 49-20) placed directly on a lead of comparable diameter and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside dimensions. The box with projectile is placed on about 4 feet of sand in a steel fragmentation tub, the detonator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fragment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourmaline gages, and the usual necessary specialized electrical circuits, shielded co-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TNT = 100." (k, m)

Unconfined charges 2 inches in diameter and 6 inches long, boostered by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. M9A1 steel cones are used. Results are averages of 4 trials.

(5) "Color."

(6) "Principal Uses."

(7) "Method of Loading."

(8) "Loading Density."

(9) "Storage."

Ammunition and bulk explosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

(a) Method: Wet or dry.

(b) Hazard Class (Quantity-Distance).

Ammunition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Materiel Command Regulation, AMCR 385-100, AMC Safety Manual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Compatibility Group.

Explosives and ammunition are grouped for compatibility with respect to the following factors:

1. Effects of explosion of the item.

2. Rate of deterioration.

3. Sensitivity to initiation.

4. Type of packing.

5. Effects of fire involving the item.

6. Quantity of explosive per unit.

(d) Exudation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

(1) Solubility.

(2) Methods of manufacture.

(3) Historical information.

(4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the Naval Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

(5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electrometric pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined). the sample of approximately 0.05 gm is introduced into soft-glass tube (~ 7 mm ID x 18 mm long) which fits over a metal peg. The volume of the space around the charge at zero gap is ~ 0.15 cc; at a gap of 0.6 mm, it is ~ 0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detonation with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead azide, mercury fulminate and nitroglycerin.

(8) Other information.

(9) References.

6. REFERENCES CITED IN INTRODUCTION.[1]

a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PATR No. 1401, 18 March 1944, Revised 28 February 1950.

b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.

c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.

d. Departments of the Army and the Air Force Joint Technical Manual and Technical Order, TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.

f. Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.

h. NDRC Interim Report, Preparation and Testing of Explosives, Nos. PT-19 and PT-20, February-April 1944.

i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.

j. Report AC-2983/Org Expl 179.

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[1] For information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

k. Eastern Laboratory, du Pont, *Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition*, NDRC Contract W-672-ORD-5723.

l. J. H. McIvor, *Fragmentation Test Procedures*, PA Testing Manual 5-1, 24 August 1950.

m. Eastern Laboratory, du Pont, *Investigation of Cavity Effect*, Final Report, 18 September 1943, NDRC Contract W-572-ORD-5723.

n. F. W. Brown, D. H. Kusler, and F. C. Gibson, *Sensitivity of Explosives to Initiation by Electrostatic Discharges*, U. S. Department of Interior, Bureau of Mines, R. I. 3852, 1946.

o. D. D. Sager, *Study of Acid Adsorption and Hydrolysis of Cellulose Nitrate and Cellulose Sulphate*, PATR No. 174, 12 January 1932.

p. L. C. Smith and E. H. Eyster, *Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests*, OSRD Report No. 5746, 27 December 1945.

q. C. S. Sandler, *An Acoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor of Rubber and Plastics*, NAVORD Report No. 1524, 1 September 1950.

W. S. Cramer, *Bulk Compressibility Data on Several Explosives*, NAVORD Report No. 4380, 15 September 1956.

Amatol, 80/20

Composition:

	%
Ammonium Nitrate	80
TNT	20
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	90
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 5 Trials

	%
Explosions	0
Partials	0
Burned	0
Unaffected	100

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	Decomposes 280
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs	0.06

100°C Heat Test:

% Loss, 1st 48 Hrs	0.03
% Loss, 2nd 48 Hrs	0.05
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

30°C, 90% RH, 2 days	61

Volatility: Nil

Molecular Weight: 92

Oxygen Balance:

CO_2 %	+1
CO %	+11

Density: gm/cc Cast 1.46

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	0.45
120°C	0.95
135°C	
150°C	6.8

200 Gram Bomb Sand Test:

Sand, gm	35.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.07

Ballistic Mortar, % TNT: (a) 130

Trauzl Test, % TNT: (b) 123

Plate Dent Test:

Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	

Detonation Rate:

Confinement	None	None
Condition	Cast	Cast
Charge Diameter, in.	1.0	1.0
Density, gm/cc	1.46	1.50
Rate, meters/second	4500	5100

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc

Charge Wt, lb

Total No. of Fragments:

For TNT

For Subject HE

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc

Charge Wt, lb

Total No. of Fragments:

For TNT

For Subject HE

Fragment Velocity: ft/sec	(f)
At 9 ft	1900
At 25½ ft	1750
Density, gm/cc	

Blast (Relative to TNT):

Air:

Peak Pressure

Impulse

Energy

Air, Confined:

Impulse

Under Water:

Peak Pressure

Impulse

Energy

Underground:

Peak Pressure

Impulse

Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Buff-yellow

Principal Uses: Bombs, HE projectiles

Method of Loading: Cast

Loading Density: gm/cc 1.46

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

Booster Sensitivity Test:	(a)
Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	0.83
Density, gm/cc	1.65

Heat of:	(d, e)
Combustion, cal/gm	1002*
Explosion, cal/gm	490*
Gas Volume, cc/gm	930*

*Calculated from composition of mixture.

Amatol, 60/40

Composition:

%	
Ammonium Nitrate	60
TNT	40
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	95
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	16
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe

Fiber Shoe

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	Decomposes 270
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs

% Loss, 2nd 48 Hrs

Explosion in 100 Hrs

Flammability Index:

Hygroscopicity: %

Volatility: Nil

Molecular Weight: 100

Oxygen Balance:

CO_2 %	-18
CO %	+ 2

Density: gm/cc Cast 1.60

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at

90°C

100°C

120°C

135°C

150°C

200 Gram Bomb Sand Test:
Sand, gm 41.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.06

Ballistic Mortar, % TNT: (a) 128

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.50
Rate, meters/second	5760

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.49
Charge Wt, lb	1.971

Total No. of Fragments:

For TNT	703
For Subject HE	583

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.57
Charge Wt, lb	0.827

Total No. of Fragments:

For TNT	514
For Subject HE	408

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:

Peak Pressure	95
Impulse	85
Energy	84

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Buff-yellow

Principal Uses: Bombs, HE projectiles

Method of Loading: Cast

Loading Density: gm/cc 1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

Heat of: (d, e)

Combustion, cal/gm	1658*
Explosion, cal/gm	633*
Gas Volume, cc/gm	980*

*Calculated from composition of mixture.

Amatol, 50/50

Composition:		
%		
Ammonium Nitrate		50
TNT		50
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		95
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		16
Sample Wt, mg		17
Friction Pendulum Test:		
Steel Shoe		Unaffected
Fiber Shoe		Unaffected
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	0	
Partials	0	
Burned	0	
Unaffected	100	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)		
1		
5	Decomposes 265	
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		
100°C Heat Test:		
% Loss, 1st 48 Hrs		
% Loss, 2nd 48 Hrs		
Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		Nil
Volatility:		

Molecular Weight:		118	
Oxygen Balance:			
CO_2 %		-27	
CO %		-3	
Density: gm/cc	Cast	1.50	
Melting Point: °C			
Freezing Point: °C			
Boiling Point: °C			
Refractive Index, n^{D}_{20}			
n^{D}_{25}			
n^{D}_{30}			
Vacuum Stability Test:			
cc/40 Hrs, at			
90°C			
100°C		<0.2	
120°C		1.0	
135°C			
150°C			
200 Gram Bomb Sand Test:			
Sand, gm		42.5	
Sensitivity to Initiation:			
Minimum Detonating Charge, gm			
Mercury Fulminate			
Lead Azide		0.20	
Tetryl		0.05	
Ballistic Mortar, % TNT:	(a)	124	
Trauzl Test, % TNT:			
Plate Dent Test:			
Method		B	
Condition		Cast	
Confined		No	
Density, gm/cc		1.55	
Brisance, % TNT		52	
Detonation Rate:			
Confinement	None		None
Condition	Cast		Cast
Charge Diameter, in.	1.0		1.0
Density, gm/cc	1.55		1.55
Rate, meters/second	6430		6230

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.55
Charge Wt, lb	2.053

Total No. of Fragments:

For TNT	703
For Subject HE	630

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.54
Charge Wt, lb	0.819

Total No. of Fragments:

For TNT	514
For Subject HE	385

Fragment Velocity: ft/sec

At 9 ft	
At 25½ ft	
Density, gm/cc	

Blast (Relative to TNT):

Air:	
Peak Pressure	97
Impulse	87
Energy	
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	93
Underground:	
Peak Pressure	104
Impulse	104
Energy	104

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones (g)
Hole Volume	53	
Hole Depth	69	

Color: Buff-yellow

Principal Uses: Bombs, HE projectiles

Method of Loading: Cast

Loading Density: gm/cc 1.59

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

Booster Sensitivity Test:	(a)
Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	0.60
Density, gm/cc	1.55

Heat of:	(d. e)
Combustion, cal/gm	1990
Explosion, cal/gm	703*
Gas Volume, cc/gm	855*

*Calculated from composition of mixture.

Specific Heat: cal/gm/°C (i)	
Temp, 20° to 80°C	0.383

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft	4000-5000

Compatibility with Metals:

Dry - Metals unaffected are zinc, iron, tin, brass, brass tin plated, brass NRC coated, brass shellac coated, nickel aluminum, steel, steel plated with nickel, zinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of ammonium nitrate is required if the maximum density of the cast amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Continue mixing to insure uniformity and load by pouring into shell or bombs.

Origin:

Developed by the British during World War I in order to conserve TNT.

References: [2]

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report 5746, 27 December 1945.

(b) Report AC-17/Phys Ex 1.

(c) D. P. McDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(d) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD Report No. 5406, 31 July 1945.

(e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(f) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

0	1	2	3	4	5	6	7	8	9
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	734	695	666	1757	838	929
950	1051	1352	1323	874	715	986	1827	1098	1129
1300	1311	1372	1493	1344	735	1376	2167	1148	1219
1530	1451	1552	1783		1145	1446		1388	1369
	1651				1225	1636		1568	1559
					1345	1796		1838	
					1455				
					1885				

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

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[2] See footnote 1, page 10.

Ammonal

Composition:	
%	
Ammonium Nitrate	22
TNT	67
Aluminum	11
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	91
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	19
Friction Pendulum Test:	
Steel Shoe	
Fiber Shoe	
Rifle Bullet Impact Test: Trials	
%	
Explosions	
Partials	
Burned	
Unaffected	
Explosion Temperature: °C	
Seconds, 0.1 (no cap used)	
1	
5	Decomposes 265
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.10
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:	102
Oxygen Balance:	
CO_2 %	-55
CO %	-22
Density: gm/cc Cast	1.65
Melting Point: °C	
Freezing Point: °C	
Boiling Point: °C	
Refractive Index, n_{20}^{D}	
n_{25}^{D}	
n_{30}^{D}	
Vacuum Stability Test:	
cc/40 Hrs, at	
90°C	
100°C	
120°C	4.4
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	47.8
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.20
Lead Azide	
Tetryl	
Ballistic Mortar, % TNT: (a)	122
Trauzl Test, % TNT:	
Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detonation Rate:	
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	
Rate, meters/second	

Ammonal

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc

Charge Wt, lb

Total No. of Fragments:

For TNT

For Subject HE

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.65
Charge Wt, lb	

Total No. of Fragments:

For TNT	655
For Subject HE	550

Fragment Velocity: ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

Blast (Relative to TNT):

Air:

Peak Pressure

Impulse

Energy

Air, Confined:

Impulse

Under Water:

Peak Pressure

Impulse

Energy

Underground:

Peak Pressure

Impulse

Energy

Preparation:

Procedure same as described under Amatols, except aluminum is added to the ammonium nitrate-TNT molten mixture under agitation until uniformity in composition is obtained. Loading is accomplished by pouring into the appropriate projectile.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Projectile filler

Method of Loading: Cast

Loading Density: gm/cc 1.65

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Origin:

Castable mixture developed in United States during World War I.

References:

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.

Ammonium Nitrate

Composition:		
%		
N	35	
H	5	NH_4NO_3
O	60	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	100+	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	31	
Sample Wt, mg	17	
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	0	
Partials	0	
Burned	0	
Unaffected	100	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)		
1		
5 Ignites	465	
10		
15		
20		
75°C International Heat Test: (a)		
% Loss in 48 Hrs	0.0	
100°C Heat Test:		
% Loss, 1st 48 Hrs	0.74	
% Loss, 2nd 48 Hrs	0.13	
Explosion in 100 Hrs	None	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH	Extreme	
Volatility:	Decomposes at 210°C	

Molecular Weight:	$(H_4N_2O_3)$	80
Oxygen Balance:		
CO_2 %		+20
CO %		+20
Density: gm/cc	Crystal	1.73
Melting Point: °C		170
Freezing Point: °C		
Boiling Point: °C		
Refractive Index,	n^D_{20}	
	n^D_{25}	
	n^D_{30}	
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		0.3
120°C		0.3
135°C		
150°C		0.3
200 Gram Bomb Sand Test:		
Sand, gm		Nil
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.25
Ballistic Mortar, % TNT: (a)		56
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:	(b)	
Confinement	None	Strong
Condition	Solid	Liquid
Charge Diameter, in.	1.25	4.5
Density, gm/cc	0.9	1.4
Rate, meters/second	1000	2500

Booster Sensitivity Test:
Condition
Tetryl, gm.
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:

Combustion, cal/gm	346
Explosion, cal/gm	346
Gas Volume, cc/gm	980
Formation, cal/gm	1098
Fusion, cal/gm	18.23

Specific Heat: cal/gm/°C (e)

°C		°C	
-150	0.189	0	0.397
-100	0.330	50	0.414
-50	0.364	100	0.428

Burning Rate:
cm/sec

Thermal Conductivity:
cal/sec/cm/°C 2.9-3.9 x 10^{-4}

Coefficient of Expansion:
Linear, %/°C

Volume, %/°C

Hardness, Mohs' Scale:

Young's Modulus:
E', dynes/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure: (g)

°C	mm Mercury
188	3.25
205	7.45
216	11.55
223	15.80
237	27.0
249	41.0

Decomposition Equation:

	(f)	(h)
Oxygen, atoms/sec (Z/sec)	$10^{13.8}$	$10^{12.3}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	40.5	38.3
Temperature Range, °C	243-261	217-267
Phase	Liquid	

Armor Plate Impact Test:

60 mm Mortar Projectile:
50% Inert, Velocity, ft/sec
Aluminum Fineness

500-lb General Purpose Bombs:

Plate Thickness, inches

1
1¼
1½
1¾

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

500-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

1000-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

3 inch HE, M42A1 Projectile, Lot KC-5:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Colorless

Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles

Method of Loading: Pressed or cast depending on composition of mixture

Loading Density: gm/cc Variable

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 12
Compatibility Group	Group D
Exudation	None

Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)

Temp. °C	PA Impact Test 2 Kg Wt, inches
25	31
75	28
100	27
150	27
175	12

Compatibility with Metals: (a)

In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.

Entropy: (g)

cal/mol at 25°C 36.0

Ammonium Nitrate

Solubility of ammonium nitrate, grams in 100 grams (%) of: (e)

Water		Alcohol		Acetic Acid		Nitric Acid			Pyridine	
°C	%	°C	%	°C	%	°C	%	% Nitric Acid	°C	%
0	118	20	2.5	16.6	0.0	0	45.1	30.0	25	~20-25
20	192	40	5	27.0	0.39	15	73.0	21.7		
40	297	60	7.5	80.9	5.8	30	106	20.8		
60	421	78	10.5	101.0	20.7	75	201	31.6		
80	580			120.0	125					
100	871									

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Ohlsson and Norrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Ammonium nitrate is decomposed by strong alkalies with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References:[3]

(a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Explosives, April 1955.

(b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Ammonium Nitrate to Explosion, PATR No. 1658, 11 July 1947.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.

G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.

(f) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(g) George Feick, The Dissociation Pressure and Free Energy of Formation of Ammonium Nitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).

(h) M. A. Cook and M. Taylor Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

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[3] See footnote 1, page 10

(i) Also see the following Picatinny Arsenal Technical Reports on Ammonium Nitrate:

0	1	2	3	4	5	6	7	8	9
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	1051	1682	1783	1094	1225	676	1947	938	1409
1290	1241		2183	1214	1455	946	2167	1008	
1720	1311			1234	1635	1106		1038	
	1391			1304	1675	1696			
	1431				1725				

Ammonium Perchlorate

Composition:

	%	
Cl	30.2	
N	11.9	NH_4ClO_4
H	3.4	
O	54.5	
C/H Ratio		

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	67
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	24
Sample Wt, mg	24

Friction Pendulum Test:

Steel Shoe	Snaps
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)

1	
5	435
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.02
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight:	(ClH_4NO_4)	117.5

Oxygen Balance:

CO_2 %	+27.3
CO %	+27.3

Density: gm/cc 1.95

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at

90°C	
100°C	0.13
120°C	0.20
135°C	
150°C	0.32

200 Gram Bomb Sand Test:

Sand, gm 6.0

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.25

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

Ammonium Perchlorate

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

3 inch HE, M42A1 Projectile, Lot KC-5:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Colorless

Principal Uses: Explosive ingredient of mixtures used in pyrotechnics and as projectile filler

Method of Loading: Pressed or cast depending on composition of mixture

Loading Density: gm/cc Variable

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

Solubility in Water
gm/100 cc saturated solution:

0°C	12
25°C	20
60°C	39
100°C	88

Preparation:

The perchlorates are prepared by the action of the acid on a suitable base; by the thermal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin).

Heat of:

Formation, cal/gm	665

Origin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parts of ammonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of ammonium perchlorate which were purified by recrystallization from hot water (German Patent, 103,993, 1898). A. Miolati mixed magnesium or calcium perchlorate with ammonium chloride and crystals of ammonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References:[4]

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.

(c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longmans, Green and Co., London, 1922, p. 396.

(d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

0	1	3	4	5	6	9
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

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[4] See footnote 1, page 10.

Composition:		
%		
Barium nitrate		67
TNT		33
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		35
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		11
Sample Wt, mg		24
Friction Pendulum Test:		
Steel Shoe		
Fiber Shoe		
Rifle Bullet Impact Test:	Trials	
	%	
Explosions		
Partials		
Burned		
Unaffected		
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)		
1		
5	Ignites	385
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		
100°C Heat Test:		
% Loss, 1st 48 Hrs		
% Loss, 2nd 48 Hrs		
Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		
30°C, 90% RH		0.00
Volatility:		

Molecular Weight:		125
Oxygen Balance:		
CO_2 %		-3
CO %		+13
Density: gm/cc	Cast	2.55
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		26.8
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.10
Ballistic Mortar, % TNT:		
Trauzl Test, % TNT:		
Plate Dent Test:	(a)	73/27
Method		B
Condition		Cast
Confined		No
Density, gm/cc		2.52
Brisance, % TNT		61
Detonation Rate:		
Confinement		
Condition		
Charge Diameter, in.		
Density, gm/cc		
Rate, meters/second		

Booster Sensitivity Test:

Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	0.32
Wax, gm	
Density, gm/cc	2.55

Heat of:

Combustion, cal/gm

Explosion, cal/gm

Gas Volume, cc/gm

Formation, cal/gm

Fusion, cal/gm 75/25 Baratol 2.8 (8)

Specific Heat: cal/gm/°C (8) 75/25 Baratol

°C		°C	
-75	0.152	75	0.280
0	0.147	85	0.213
25	0.160	90	0.201
50	0.229	100	0.171

Burning Rate:

cm/sec

Thermal Conductivity:

cal/sec/cm/°C

Coefficient of Expansion:

Linear, %/°C

Volume, %/°C

Hardness, Mohs' Scale:

Young's Modulus:

E', dynes/cm²

E, lb/inch²

Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure:

°C mm Mercury

Decomposition Equation:

Oxygen, atoms/sec

(Z/sec)

Heat, kilocalorie/mole

(ΔH, kcal/mol)

Temperature Range, °C

Phase

Armor Plate Impact Test:

60 mm Mortar Projectile:

50% Inert, Velocity, ft/sec

Aluminum Fineness

500-lb General Purpose Bombs:

Plate Thickness, inches

1

1¼

1½

1¾

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

500-lb General Purpose Bomb vs Concrete:

Height, ft

Trials

Unaffected

Low Order

High Order

1000-lb General Purpose Bomb vs Concrete:

Height, ft

Trials

Unaffected

Low Order

High Order

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

3 inch HE, M42A1 Projectile, Lot KC-5:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Bomb filler

Method of Loading: Cast

Loading Density: gm/cc 2.55

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

Preparation:

The appropriate weight of barium nitrate heated to about 90°C is added to molten TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature.

Origin:

Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.

Baratol

References:[5]

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(b) L. C. Smith and E. G. Wyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

0	3	6	8